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The program goal is to determine the applicability of novel energetic materials developed over the last few years, largely under funding by the Office of Naval Research, in electro-thermal chemical (plasma ignited) gun propellants. Particular interest lies in whether the new ingredients can achieve the desired ballistic response and energy goals for this system. A series of extensive thermochemical calculations on a wide range of potential formulations have been completed.

A summary of the data generated has been prepared for distribution to an advisory team. Further activity has begun on procurement of critical materials that are essential for the additional tasks, including some initial formulation safety (compatibility) tests.

The baseline study focused on sixteen different formulations, containing 24% binder as a representative level with a primary solid making up the bulk of the formulation. A secondary solid was added at five percentages: 0,6,12,18, and 24 percent.

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PROGRESS REPORT

CDRL A001 - CLIN 0002

ADVANCED ETC GUN PROPELLANT

CONTRACT: N00014-95-C-0245

MARCH 1996

Progress on ETC Gun program:

Background:
The program goal is to determine the applicability of novel energetic materials developed over the last few years, largely under funding by the Office of Naval Research, in electro-thermal chemical (plasma ignited) gun propellants. Particular interest lies in whether the new ingredients can achieve the desired ballistic response and energy goals for this system. The program is divided into four tasks, three of which will be addressed under this effort. The first is a series of extensive thermochemical calculations on a wide range of potential formulations. The second is formulation development and selection. The third is a formulation scale-up for plasm ignition and 30 mm gun firing tests. The fourth task will be a scale-up to a full 5" round and a series of firings in that gun.

Progress:
To date, the thermochemical calculations, described as Task 1 in the previous section, have been completed. A summary of the data generated has been prepared for distribution to an advisory team. Further activity has begun on procurement of critical materials that are essential for the second and third tasks, including some initial formulation safety (compatibility) tests.

A one-page, graphic summary of the calculations is included as figure 1 (attached). The data from several hundred thermochemical calculations are reported with the temperature on the 'y-axis' and the ballistic energy (impetus times density divided by gamma minus 1). The baseline study focused on sixteen different formulations reported on this graph. A summary of the formulations is given in table 1. All formulations contained 24% binder as a representative level in this summary. Other solids loadings were calculated and the data are also available. The primary solid makes up the bulk of the formulation. The secondary solid was added at five percentages: 0, 6, 12, 18, and 24 percent. These five values are reported for each formulation in figure 1. The 0 percent value for each formulation can be identified by both the symbol for the nitroguanidine (NQ) adn the trinitroazetidine (TNAZ) secondary solid being on top of one another. The addition of additive gives values progressively further away from the 0 percent in a linear fashion.

TABLE 1. Formulations for Summary Figure

Abbreviation	BINDER	BINDER TYPE	PRIMARY SOLID	SECONDARY SOLID
BEERDXNQ	BEMO-EMMO	ether	RDX	NQ
BEERDXTN	BEMO-EMMO	ether	RDX	TNAZ
BEECL2NQ	BEMO-EMMO	ether	CL-20	NQ
BEECL2TN	BEMO-EMMO	ether	CL-20	TNAZ
BENRDXNQ	BEMO-NMMO	nitrate ester	RDX	NQ
BENRDXTN	BEMO-NMMO	nitrate ester	RDX	TNAZ
BENCL2NQ	BEMO-NMMO	nitrate ester	CL-20	NQ
BENCL2TN	BEMO-NMMO	nitrate ester	CL-20	TNAZ
BNMRDXNQ	BAMO-NMMO	azide + nitrate ester	RDX	NQ
BNMRDXTN	BAMO-NMMO	azide + nitrate ester	RDX	TNAZ
BNMCL2NQ	BAMO-NMMO	azide + nitrate ester	CL-20	NQ
BNMCL2TN	BAMO-NMMO	azide + nitrate ester	CL-20	TNAZ
BARDXNQ	BAMO-AMMO	azide	RDX	NQ
BARDXTN	BAMO-AMMO	azide	RDX	TNAZ
BACL2NQ	BAMO-AMMO	azide	CL-20	NQ
BACL2TN	BAMO-AMMO	azide	CL-20	TNAZ

Several conclusions are obvious from figure 1. First, the energy content of the "ether" and "nitrate ester" binders is too low to be of significant interest at 76 percent solids with the possible exception of BEMO-NMMO with CL-20. Second, the BAMO-NMMO formulations are inherently most energetic. Third, NQ replacement of RDX or CL-20 drops the ballistic energy very rapidly. Fourth, TNAZ addition raises the energy slightly over RDX but lowers the energy when replacing CL-20. A suggestion of six

formulations for evaluation in Task 2 is given in Table 2. These formulations cover a wide range of different ingredient mixtures while all exhibiting similar ballistic energy and flame temperatures. This range will provide a good test of the range of effect possible with an electrical input on this class of formulations.

TABLE 2. Formulations for Task 2

Binder	Primary solid	Secondary solid	Percentage of secondary solid
BAMO-AMMO	CL-20	none	n/a
BAMO-NMMO	CL-20	NQ	12
BAMO-AMMO	CL-20	TNAZ	24
BAMO-NMMO	CL-20	none	n/a
BAMO-NMMO	RDX	TNAZ	24
BEMO-NMMO	CL-20	none	n/a

Plans:
The data package will be distributed and final selection of about 6 propellants for initial screening will be made (transition out of Task 1). These formulations will be prepared, screened for acceptable safety properties, and characterized ballistically (Task 2). Selection will be made of three propellants for examination in plasma ignition and 30 mm firings (Task 3). It is planned that Task 1 be completed (including review and formulation selection) on March 31. Task 2 will last three months including data reduction and formulation selection. Task 3 will require 2 months for propellant grain preparation and shipping to test facilities (August 31 completion date).

76% SOLIDS TPE PROPELLANTS

Oxetanes with CL20, RDX, NQ, TNAZ